MACROECONOMICS

LECTURE 9

ECONOMIC GROWTH II:
TECHNOLOGY, EMPIRICS, AND POLICY

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Outline

9-1 Technological Progress in the Solow Model

9-2 From Growth Theory to Growth Empirics

9-3 Policies to Promote Growth

9-4 Beyond the Solow Model: Endogenous Growth Theory

9-5 Conclusion

- Our analysis of the forces governing **long-run growth**
- **Tasks:**

1st to make the Solow model more general and realistic.

- The Solow model does not explain ***technological progress but, instead, takes it as exogenously.***

2nd to move from theory to empirics.

- The Solow model can shed much light on international growth experiences, but it is far from the last word on the subject.

3d to examine how a nation's public policies can infl uence the level and growth of its citizens' standard of living.

1. Should our society **save more** or less?
2. How can **policy infl uence the rate of saving**?
3. Are there **some types of investment** that policy should especially encourage?
4. **What institutions** ensure that the economy's resources are put to their best use?
5. How can **policy increase the rate of TLP**?

- The Solow growth model provides the theoretical framework within which we consider these policy issues.

4th to consider what the Solow model leaves out.

- We examine a new set of theories, called ***endogenous growth theories***, which help to explain the TLP that the Solow model takes as exogenous.

9-1 Technological Progress in the Solow Model

- The Efficiency of Labor
- The Steady State With Technological Progress
- The Effects of Technological Progress

- $Y = (K, L)$
- $Y = (K, L * E)$
- where *E* is the **efficiency of labor.**
  - the available technology improves, the efficiency of labor rises, and each hour of work contributes more to the production of goods and services.
  - The term ***L* * *E*** can be interpreted as measuring the **effective number of workers.**
- *L* measures the number of workers in the labor force,
- $L \times E$ measures both the workers and the technology with which the typical worker comes equipped.
- The simplest assumption about TLP is that it causes the *E* to grow at some **constant rate** *g*.
  - **For example**, if $g = 0.02$,
  - then each unit of labor becomes 2% more efficient each year: output increases as if the labor force had increased by 2 percent more than it really did.
- This form of TLP is called ***labor augmenting,*** and ***g*** is called the rate of **labor-augmenting T/LP.**

The ***L*** is growing at ***n***, and
the ***E*** is growing at ***g***,
the $L \times E$ is growing at $n + g$.

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9-1 Technological Progress in the Solow Model

The Efficiency of Labor
The Steady State With Technological Progress
The Effects of Technological Progress

- Because T/LP is modeled here as labor augmenting, it fits into the model in much the same way as population growth.
- When there was no T/LP, we analyzed the economy in terms of quantities per worker;
- We now let
  - $k = K/(L \times E)$ stand for capital per effective worker
  - $y = Y/(L \times E)$ stand for output per effective worker.
  - => $y = f(k)$.
- $\Delta k = sf(k) - (\delta + n + g)k$.
- to keep k constant,
  - δk is needed to replace depreciating capital,
  - nk is needed to provide capital for new workers,
  - gk is needed to provide capital for the new "effective workers" created by T/LP.

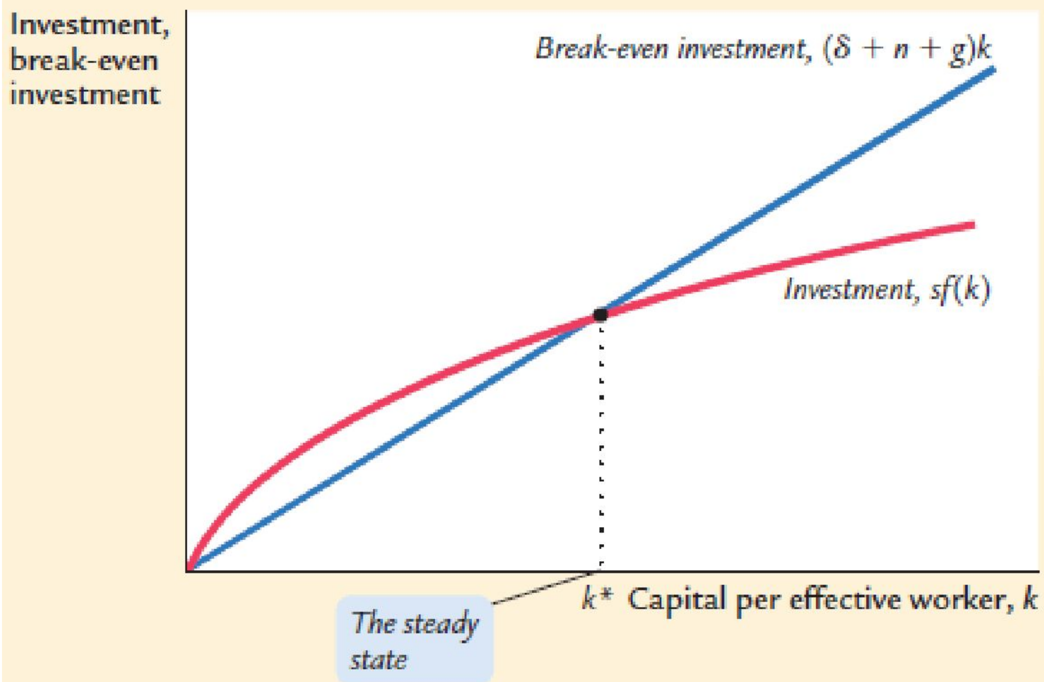
9-1 Technological Progress in the Solow Model

T/LP
the Solow Growth Model

Now that k is defined as the amount of capital per effective worker, increases in the effective number of workers because of T/LP tend to decrease k.

In the SS, investment $sf(k)$ exactly offsets the reductions in k attributable to depreciation, population growth, and T/LP.

FIGURE 9-1



9-1 Technological Progress in the Solow Model

TABLE 9-1

Steady-State Growth Rates in the Solow Model With Technological Progress

Variable	Symbol	Steady-State Growth Rate
Capital per effective worker	$k = K/(E \times L)$	0
Output per effective worker	$y = Y/(E \times L) = f(k)$	0
Output per worker	$Y/L = y \times E$	g
Total output	$Y = y \times (E \times L)$	$n + g$

a high rate of saving leads to a high rate of growth only until the steady state is reached.
Once the economy is in steady state, the rate of growth of output per worker depends only on the rate of technological progress.
According to the Solow model, only technological progress can explain sustained growth and persistently rising living standards.
steady-state consumption per effective worker is
$c* = f(k*) - (\delta + n + g)k*$.
Steady-state consumption is maximized if $MPK - \delta = n + g$.
That is, **at the Golden Rule level of capital,**

- the net marginal product of capital, $MPK - \delta$, =
- the rate of growth of total output, $n + g$.

9-2 From Growth Theory to Growth Empirics

- **Balanced Growth**
- Convergence
- Factor Accumulation Versus Production Efficiency

- Ehe Solow model T/LP causes the values of many variables to rise together in the steady state. This property is called **balanced growth.**

Example: The long-run data for the U.S. economy.

- **Y/L, K/L** have in fact grown at ≈2% per year.
- **K/Y** has remained ≈ constant over time.
- **The real rental price of capital** is constant over time. (measured as real capital income divided by the capital stock)
- **The real wage** has increased ≈ 2 % per year;

- Marx predicted that the return to capital would decline over time and that this would lead to economic and political crisis.
  - Economic history has not supported Marx's prediction

9-2 From Growth Theory to Growth Empirics

- Balanced Growth
- **Convergence**
- Factor Accumulation Versus Production Efficiency

- If economies that **start off poor** subsequently **grow faster** than economies that **start off rich**,
  - then the world's poor economies will tend to **catch up** with the world's rich economies.
  - This process of catch-up is called **convergence.**

- If convergence does not occur, then countries that start off behind are likely to remain poor.

The Solow model makes clear predictions:

1. **2 economies start off with**
   - ✔ different ***k***,
   - ✔ the same **SS**, as determined by their ***s***, population ***n***, and ***E*** of ***L***.
   - ✔ => we should **expect** the 2 economies to converge;
2. **if 2 economies have**
   - ✔ different **SS**, perhaps because the economies have
   - ✔ different ***s***, then we should **not expect** convergence.
   - ✔ Each economy will approach its own **SS**.

9-2 From Growth Theory to Growth Empirics

- In samples of economies with similar cultures and policies, studies find that economies converge at a rate of about 2% per year.
  - The gap between rich and poor economies closes by about 2% each year.

An example: the economies of individual American states.

- When researchers examine only data on income per person, they find little evidence of convergence:
  - countries that **start off poor** do **not grow faster** on average than countries **that start off rich**.
  - This finding suggests that different countries have **different SS**.
- The economies of the world exhibit ***conditional convergence*:**

they appear to be converging to their own SS, which are determined by

- **saving,**
- **population growth,**
- **human capital.**

9-2 From Growth Theory to Growth Empirics

- Balanced Growth
- Convergence
- **Factor Accumulation Versus Production Efficiency**

In terms of the Solow model

the large gap between rich and poor is explained by differences in

1. the **F/P**: quantities of ***K & L*** or capital accumulation ***(K,L)***
   - Poor = lacks tools and skills,
2. the **PF:** the ***E*** with which economies use **F/P**
   - Poor = the tools and skills are not being put to their best use.

- Much research has attempted to estimate the relative importance of these two sources of income disparities.
- A common finding is that they are positively correlated: **nations with high levels of physical and human capital also tend to use those factors efficiently.**

9-2 From Growth Theory to Growth Empirics

- Balanced Growth
- Convergence
- **Factor Accumulation Versus Production Efficiency**

There are several ways to interpret this positive correlation:

1. **An efficient economy** may encourage capital accumulation.
   - greater resources and incentive to stay in school and accumulate human capital.
2. **Capital accumulation** may induce greater efficiency.
   - countries that save and invest more will appear to have better production functions.
3. Both factor accumulation and production efficiency are driven by the **quality of the nation's institutions**
   - Bad policy:
     - ✔ high inflation,
     - ✔ excessive budget deficits,
     - ✔ widespread market interference, and
     - ✔ rampant corruption,
     - ✔ often go hand in hand.
   - => Economies **accumulate less capital and fail to use the capital they have as efficiently as they might.**

Is Free Trade Good for Economic Growth?

- At least **since Adam Smith**, economists have advocated *free trade* as a policy that promotes national prosperity.
- Today, economists make the case with greater rigor, relying on **David Ricardo's** theory of *comparative advantage* as well as more modern theories of *international trade.*

According to these theories, a nation open to trade can achieve greater production efficiency and a higher standard of living by specializing in those goods for which it has a comparative advantage.

1. 1 approach is to *look at international data* to see if countries that are
   - *open to trade typically enjoy greater prosperity*. The evidence shows that they do.
2. 2nd approach is to *look at what happens* when
   - *closed economies remove their trade restrictions*. Once again**, Smith's** hypothesis fares well.
3. 3rd approach to *measuring the impact of trade on growth*, proposed by economists **Jeffrey Frankel and David Romer,** is *to look at*
   - the *impact of geography*. Some countries trade less simply because they are geographically disadvantaged.

Case Study

9-3 Policies to Promote Growth

- Evaluating the Rate of Saving
- Changing the Rate of Saving
- Allocating the Economy's Investment
- Establishing the Right Institutions
- Encouraging Technological Progress

The U.S. economy is at, above, or below the GR SS?

- we need to compare $MPK - \delta$ *with the growth rate of total output* $(n + g)$.
- At the ***GR SS***: $MPK - \delta = n + g$.

1. If the economy is operating with **<** capital than in the GR**SS**, then
   1. Diminishing MPC tells us that $MPK - \delta > n + g$. →
   2. ↑***ing the s*** => to
      1. ↑ capital accumulation and economic growth
      2. a **SS** with ↑er ***K***

         (although ***K*** will be ↓er for part of the transition to the new **SS**).
2. If the economy has **>** capital than in the GR **SS**, then
   1. $MPK - \delta < n + g$. → capital accumulation is excessive:
   2. **reducing the *s*** => to
      1. ↑er ***K*** both immediately and in the long run.

9-3 Policies to Promote Growth

Example:

Real GDP in the U.S. grows an average of 3% per year

$n + g = 0.03.$

- **We can estimate the net MPC** from:

1. The CS is about 2.5 times one year's GDP. $k = 2.5y$

2. Depreciation of capital is about 10% of GDP. $\delta k = 0.1y$

- **3. Capital income is about 30% of GDP.** $MPK \times k = 0.3y$

- We solve for **the rate of depreciation** *by dividing equation 2 by equation 1:*
  - $\delta k/k = (0.1y)/(2.5y)$; $\delta = 0.04.$
- And we solve for **the MPK by dividing** *equation 3 by* equation 1:
  - $(MPK \times k)/k = (0.3y)/(2.5y)$; $MPK = 0.12.$

9-3 Policies to Promote Growth

- **Evaluating the Rate of Saving**
- Changing the Rate of Saving
- Allocating the Economy's Investment
- Establishing the Right Institutions
- Encouraging Technological Progress

- Thus,
  1. about 4% of the ***k*** depreciates each year, and
  2. the ***MPC*** is about 12% per year.
  3. The net MPC *is about 8% per year.*
- We can now see that
  - the return to capital (***MPK* − δ = *8%* per year**) *is* <u>*well*</u> in excess of
  - the economy's average growth rate (***n* + *g* = *3%* per year**).
- This fact indicates that the CS in the U.S. economy is **<u>below</u>** the GRL.
  - If the U.S. saved & invested a ↑er fraction of its income,
  - it would grow more rapidly and reach a SS with ↑er *C*.

9-3 Policies to Promote Growth

- Evaluating the Rate of Saving
- **Changing the Rate of Saving**
- Allocating the Economy's Investment
- Establishing the Right Institutions
- Encouraging Technological Progress

The preceding calculations show that to move the U.S. economy toward the Golden Rule steady state, policymakers should increase national saving. But how can they do that? We saw in Chapter 3 that, as a matter of sheer accounting, higher national saving means higher public saving, higher private saving, or some combination of the two. Much of the debate over policies to increase growth centers on which of these options is likely to be most effective.

The most direct way in which the government affects national saving is through public saving—the difference between what the government receives in tax revenue and what it spends. When its spending exceeds its revenue, the government runs a *budget defi cit*, which represents negative public saving. As we saw in Chapter 3, a budget defi cit raises interest rates and crowds out investment; the resulting reduction in the capital stock is part of the burden of the national debt on future generations. Conversely, if it spends less than it raises in revenue, the government runs a *budget surplus*, which it can use to retire some of the national debt and stimulate investment.

The government also affects national saving by infl uencing private saving—the saving done by households and fi rms. In particular, how much people decide to save depends on the incentives they face, and these incentives are altered by a variety of public policies. Many economists argue that high tax rates on capital—including the corporate income tax, the federal income tax, the estate tax, and many state income and estate taxes—discourage private saving by reducing the rate of return that savers earn. On the other hand, tax-exempt retirement accounts, such as IRAs, are designed to encourage private saving by giving preferential treatment to income saved in these accounts. Some economists have proposed increasing the incentive to save by replacing the current system of income taxation with a system of consumption taxation.

Many disagreements over public policy are rooted in different views about how much private saving responds to incentives. For example, suppose that the government increased the amount that people could put into tax-exempt retirement accounts. Would people respond to this incentive by saving more? Or, instead, would people merely transfer saving already done in other forms into these accounts—reducing tax revenue and thus public saving without any stimulus to private saving? The desirability of the policy depends on the answers to these questions. Unfortunately, despite much research on this issue, no consensus has emerged.

9-3 Policies to Promote Growth

The Solow model makes the simplifying assumption that there is only one type of capital. In the world, of course, there are many types. Private businesses invest in traditional types of capital, such as bulldozers and steel plants, and newer types of capital, such as computers and robots. The government invests in various forms of public capital, called *infrastructure*, such as roads, bridges, and sewer systems. In addition, there is *human capital*—the knowledge and skills that workers acquire through education, from early-childhood programs such as Head Start to on-thejob training for adults in the labor force. Although the capital variable in the Solow model is usually interpreted as including only physical capital, in many ways human capital is analogous to physical capital. Like physical capital, human capital increases our ability to produce goods and services. Raising the level of human capital requires investment in the form of teachers, libraries, and student time. Research on economic growth has emphasized that human capital is at least as important as physical capital in explaining international differences in standards of living. One way of modeling this fact is to give the variable we call "capital" a broader defi nition that includes both human and physical capital.6

Policymakers trying to promote economic growth must confront the issue of what kinds of capital the economy needs most. In other words, what kinds of capital yield the highest marginal products? To a large extent, policymakers can rely on the marketplace to allocate the pool of saving to alternative types of investment. Those industries with the highest marginal products of capital will naturally be most willing to borrow at market interest rates to fi nance new investment. Many economists advocate that the government should merely create a "level playing fi eld" for different types of capital—for example, by ensuring that the tax system treats all forms of capital equally. The government can then rely on the market to allocate capital effi ciently.

Other economists have suggested that the government should actively encourage particular forms of capital. Suppose, for instance, that technological advance

9-3 Policies to Promote Growth

- Evaluating the Rate of Saving
- Changing the Rate of Saving
- **Allocating the Economy's Investment**
- Establishing the Right Institutions
- Encouraging Technological Progress

- occurs as a by-product of certain economic activities. This would happen if new
- and improved production processes are devised during the process of building
- capital (a phenomenon called *learning by doing*) and if these ideas become part of
- society's pool of knowledge. Such a by-product is called a *technological externality*
- (or a *knowledge spillover*). In the presence of such externalities, the social returns to
- capital exceed the private returns, and the benefi ts of increased capital accumulation
- to society are greater than the Solow model suggests.7 Moreover, some types
- of capital accumulation may yield greater externalities than others. If, for example,
- installing robots yields greater technological externalities than building a new steel
- mill, then perhaps the government should use the tax laws to encourage investment
- in robots. The success of such an *industrial policy*, as it is sometimes called, requires
- that the government be able to accurately measure the externalities of different
- economic activities so it can give the correct incentive to each activity.
- Most economists are skeptical about industrial policies for two reasons. First,
- measuring the externalities from different sectors is virtually impossible. If policy is
- based on poor measurements, its effects might be close to random and, thus, worse
- than no policy at all. Second, the political process is far from perfect. Once the
- government gets into the business of rewarding specifi c industries with subsidies
- and tax breaks, the rewards are as likely to be based on political clout as on the
- magnitude of externalities.
- One type of capital that necessarily involves the government is public capital.
- Local, state, and federal governments are always deciding if and when they should
- borrow to fi nance new roads, bridges, and transit systems. In 2009, one of President
- Barack Obama's fi rst economic proposals was to increase spending on such
- infrastructure. This policy was motivated by a desire partly to increase short-run
- aggregate demand (a goal we will examine later in this book) and partly to provide
- public capital and enhance long-run economic growth. Among economists,
- this policy had both defenders and critics. Yet all of them agree that measuring
- the marginal product of public capital is diffi cult. Private capital generates an easily
- measured rate of profi t for the fi rm owning the capital, whereas the benefi ts
- of public capital are more diffuse. Furthermore, while private capital investment
- is made by investors spending their own money, the allocation of resources for
- public capital involves the political process and taxpayer funding. It is all too
- common to see "bridges to nowhere" being built simply because the local senator
- or congressman has the political muscle to get funds approved.
- 7Paul Romer,

4 Industrial Policy in Practice

- Policymakers and economists have long debated whether the government should
- promote certain industries and fi rms because they are strategically important
- for the economy. In the United States, the debate goes back over two centuries.
- Alexander Hamilton, the fi rst U.S. Secretary of the Treasury, favored tariffs on
- certain imports to encourage the development of domestic manufacturing.
- The Tariff of 1789 was the second act passed by the new federal government.
- The tariff helped manufacturers, but it hurt farmers, who had to pay more for
- foreign-made products. Because the North was home to most of the manufacturers,
- while the South had more farmers, the tariff was one source of the
- regional tensions that eventually led to the Civil War.
- Advocates of a signifi cant government role in promoting technology can point
- to some recent successes. For example, the precursor of the modern Internet is
- a system called Arpanet, which was established by an arm of the U.S. Department
- of Defense as a way for information to fl ow among military installations.
- There is little doubt that the Internet has been associated with large advances in
- productivity and that the government had a hand in its creation. According to
- proponents of industrial policy, this example illustrates how the government can
- help jump-start an emerging technology.
- Yet governments can also make mistakes when they try to supplant private
- business decisions. Japan's Ministry of International Trade and Industry (MITI)
- is sometimes viewed as a successful practitioner of industrial policy, but it once
- tried to stop Honda from expanding its business from motorcycles to automobiles.
- MITI thought that the nation already had enough car manufacturers.
- Fortunately, the government lost this battle, and Honda turned into one of the
- world's largest and most profi table car companies. Soichiro Honda, the company's
- founder, once said, "Probably I would have been even more successful had we
- not had MITI."
- Over the past several years, government policy has aimed to promote "green
- technologies." In particular, the U.S. federal government has subsidized the production
- of energy in ways that yield lower carbon emissions, which are thought
- to contribute to global climate change. It is too early to judge the long-run success
- of this policy, but there have been some short-run embarrassments. In 2011,
- a manufacturer of solar panels called Solyndra declared bankruptcy two years
- after the federal government granted it a $535 million loan guarantee. Moreover,
- there were allegations that the decision to grant the loan guarantee had been
- politically motivated rather than based on an objective evaluation of Solyndra's
- business plan. As this book was going to press, the Solyndra case was under investigation
- by congressional committees and the FBI.
- The debate over industrial policy will surely continue in the years to come.
- The fi nal judgment about this kind of government intervention in the market
- requires evaluating both the effi ciency of unfettered markets and the ability of
- governmental institutions to identify technologies worthy of support. ■

Case Study

9-3 Policies to Promote Growth

As we discussed earlier, economists who study international differences in the standard of living attribute some of these differences to the inputs of physical and human capital and some to the productivity with which these inputs are used. One reason nations may have different levels of production effi ciency is that they have different institutions guiding the allocation of scarce resources. Creating the right institutions is important for ensuring that resources are allocated to their best use.

A nation's legal tradition is an example of such an institution. Some countries, such as the United States, Australia, India, and Singapore, are former colonies of the United Kingdom and, therefore, have English-style common-law systems. Other nations, such as Italy, Spain, and most of those in Latin America, have legal traditions that evolved from the French Napoleonic Code. Studies have found that legal protections for shareholders and creditors are stronger in English-style than Frenchstyle legal systems. As a result, the English-style countries have better-developed capital markets. Nations with better-developed capital markets, in turn, experience more rapid growth because it is easier for small and start-up companies to fi nance investment projects, leading to a more effi cient allocation of the nation's capital.8

Another important institutional difference across countries is the quality of government itself. Ideally, governments should provide a "helping hand" to the market system by protecting property rights, enforcing contracts, promoting competition, prosecuting fraud, and so on. Yet governments sometimes diverge from this ideal and act more like a "grabbing hand" by using the authority of the state to enrich a few powerful individuals at the expense of the broader community. Empirical studies have shown that the extent of corruption in a nation is indeed a signifi cant determinant of economic growth.9

Adam Smith, the great eighteenth-century economist, was well aware of the role of institutions in economic growth. He once wrote, "Little else is requisite to carry a state to the highest degree of opulence from the lowest barbarism but peace, easy taxes, and a tolerable administration of justice: all the rest being brought about by the natural course of things." Sadly, many nations do not enjoy these three simple advantages.

The Colonial Origins of Modern Institutions

Case Study

International data show a remarkable correlation between latitude and economic prosperity: nations closer to the equator typically have lower levels of income per person than nations farther from the equator. This fact is true in both the northern and southern hemispheres.

What explains the correlation? Some economists have suggested that the tropical climates near the equator have a direct negative impact on productivity. In the heat of the tropics, agriculture is more diffi cult, and disease is more prevalent. This makes the production of goods and services more diffi cult.

Although the direct impact of geography is one reason tropical nations tend to be poor, it is not the whole story. Research by Daron Acemoglu, Simon Johnson, and James Robinson has suggested an indirect mechanism—the impact of geography on institutions. Here is their explanation, presented in several steps:

1. In the seventeenth, eighteenth, and nineteenth centuries, tropical climates presented European settlers with an increased risk of disease, especially malaria and yellow fever. As a result, when Europeans were colonizing much of the rest of the world, they avoided settling in tropical areas, such as most of Africa and Central America. The European settlers preferred areas with more moderate climates and better health conditions, such as the regions that are now the United States, Canada, and New Zealand.

2. In those areas where Europeans settled in large numbers, the settlers established European-like institutions that protected individual property rights and limited the power of government. By contrast, in tropical climates, the colonial powers often set up “extractive” institutions, including authoritarian governments, so they could take advantage of the area’s natural resources. These institutions enriched the colonizers, but they did little to foster economic growth.

3. Although the era of colonial rule is now long over, the early institutions that the European colonizers established are strongly correlated with the modern institutions in the former colonies. In tropical nations, where the colonial powers set up extractive institutions, there is typically less protection of property rights even today. When the colonizers left, the extractive institutions remained and were simply taken over by new ruling elites.

4. The quality of institutions is a key determinant of economic performance. Where property rights are well protected, people have more incentive to make the investments that lead to economic growth. Where property rights are less respected, as is typically the case in tropical nations, investment and growth tend to lag behind.

This research suggests that much of the international variation in living standards that we observe today is a result of the long reach of history.

9-3 Policies to Promote Growth

- Evaluating the Rate of Saving
- Changing the Rate of Saving
- Allocating the Economy's Investment
- Establishing the Right Institution
- **Encouraging Technological Progress**

The Solow model shows that sustained growth in income per worker must come
from technological progress. The Solow model, however, takes technological
progress as exogenous; it does not explain it. Unfortunately, the determinants of
technological progress are not well understood.
Despite this limited understanding, many public policies are designed to stimulate
technological progress. Most of these policies encourage the private sector to
devote resources to technological innovation. For example, the patent system gives
a temporary monopoly to inventors of new products; the tax code offers tax breaks
for fi rms engaging in research and development; and government agencies, such as
the National Science Foundation, directly subsidize basic research in universities. In
addition, as discussed above, proponents of industrial policy argue that the government
should take a more active role in promoting specifi c industries that are key
for rapid technological advance.
In recent years, the encouragement of technological progress has taken on
an international dimension. Many of the companies that engage in research
to advance technology are located in the United States and other developed
nations. Developing nations such as China have an incentive to "free ride" on
this research by not strictly enforcing intellectual property rights. That is, Chinese
companies often use the ideas developed abroad without compensating the
patent holders. The United States has strenuously objected to this practice, and
China has promised to step up enforcement. If intellectual property rights were

The Worldwide Slowdown in Economic Growth

TABLE 9-2

Growth Around the World

Country	GROWTH IN OUTPUT PER PERSON (PERCENT PER YEAR) 1948–1972	1972–1995	1995–2010
Canada	2.9	1.8	1.6
France	4.3	1.6	1.1
West Germany	5.7	2.0	
Germany			1.3
Italy	4.9	2.3	0.6
Japan	8.2	2.6	0.6
United Kingdom	2.4	1.8	1.7
United States	2.2	1.5	1.5

Source: Angus Maddison, *Phases of Capitalist Development* (Oxford: Oxford University Press, 1982); *OECD National Accounts*; and World Bank: *World Development Indicators*.

- **Measurement Problems**

For instance,

- if technological advance leads to **more** computers being built,
  - then the increase in output and productivity is easy to measure.
- If technological advance leads to **faster** computers being built,
  - then output and productivity have increased, but that increase is more subtle and harder to measure.

Case Study

- **Oil Prices** Productivity growth slowed at the same time that oil prices skyrocketed
- **Worker Quality** The quality of education was declining. This could explain slowing productivity growth
- **The Depletion** of Ideas In the early 1970s the world started running out of new ideas about how to produce, pushing the economy into an age of slower technological progress.

9-4 Beyond the Solow Model: Endogenous Growth Theory

- **Endogenous Growth Theory** reject the Solow model's assumption of exogenous technological change.

Y* = *AK,

- ***Y*** is output, ***K*** is the capital stock, ***A*** is a constant measuring the amount of *Y* produced for each unit of *K*.
- PF does not exhibit the property of diminishing returns to capital.

$$K = sY - K\delta.$$

- $Y/Y = K/K = sA - \delta$.
- $sA > \delta$, the economy's income grows forever, even without the assumption of exogenous T/LP.

Growth Theory :	exogenous	Endogenous
Returns:	diminishing	Constant
Model:	Solow	New models
capital:	equipment, etc.	Include knowledge
Growth:	temporary till SS, then it needs T/LP for growth	Persistent, Without T/LP

9-4 Beyond the Solow Model: Endogenous Growth Theory

$$Y = F[K, (1 - u)LE] \text{ (PF in manufacturing firms),}$$
$$E = g(u)E \text{ (PF in research universities),}$$
$$K = sY - K \text{ (capital accumulation),}$$

u is the fraction of the labor force in universities

1 − *u* is the fraction in manufacturing,

E is the stock of knowledge (efficiency of labor),

g is a function that shows how the growth in knowledge ~ on the fraction of the labor force in universities.

Assumtion:

<u>The PF for the MF have constant returns to scale.</u>

- **This model is a cousin** of the ***Y* = *AK* model.**
  - This economy exhibits constant returns to capital, as long as capital is broadly defined to include knowledge. Persistent growth arises endogenously because the creation of knowledge in universities never slows down.
- **This model is also a cousin** of ***the Solow growth model.***
  - If ***u*** is held constant, then the ***E*** grows at the constant rate ***g*(*u*).** This result of constant growth in the ***E*** of labor at rate ***g*** is precisely the assumption made in the Solow model with T/LP.
  - For any given value of *u*, this endogenous growth model works just like the Solow model.

9-4 Beyond the Solow Model: Endogenous Growth Theory

2 key decision variables in this model.

- As in the Solow model,
  - ***s*** determines the **SS** ***stock of K.***
  - ***u*** determines the growth in the ***stock of knowledge***.
  - ***s & u*** affect the ***level of income***
  - ***u*** affects the ***SS growth rate of income***.
- Thus, this model of endogenous growth takes a small step in the direction of showing
  - which societal decisions determine **the rate of technological change.**

9-4 Beyond the Solow Model: Endogenous Growth Theory

- The Basic Model
- A Two-Sector Model
- **The Microeconomics of Research and Development**
- The Process of Creative Destruction

- 1. knowledge is largely a public goodю, much research is done in firms that are driven by the profit motive.
- 2. research is profitable because
  - innovations give firms temporary monopolies,
  - of the patent system
  - there is an advantage to being the first firm on the market with a new product.
- 3. when one firm innovates, other firms build on that innovation to produce the next generation of innovations.
- These (essentially microeconomic) facts are not easily connected with the (essentially macroeconomic) growth models we have discussed so far.
- Some endogenous growth models try to incorporate these facts about

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- Is the **social return** to research greater or smaller than the **private return** ?

- 1. When a firm **creates a new technology,** it makes other firms better off by giving them a base of knowledge on which to build in future research.
  - the **"standing on shoulders"** externality
  - The social return to research is large—often in excess of **40%** per year
- 2. When one firm **invests in research,** it can make other firms worse off if it does little more than become the first to discover a technology that another firm would have invented in due course.
  - the **"stepping on toes" effect.**
  - The return to physical capital is about **8%** per year.

This finding justifies substantial government subsidies to research.

9-4 Beyond the Solow Model: Endogenous Growth Theory

- The Basic Model
- A Two-Sector Model
- The Microeconomics of Research and Development
- **The Process of Creative Destruction**

- In his 1942 book Capitalism, Socialism, and Democracy, economist Joseph Schumpeter suggested that economic progress comes through a process of creative destruction.
- According to Schumpeter, the driving force behind progress is the entrepreneur with an idea for a new product, a new way to produce an old product, or some other innovation.

Examples:

- In England in the early 19 century, an important innovation was the invention and spread of machines that could produce textiles using unskilled workers at low cost.
  - Term “Luddite” refers to anyone who opposes technological progress.
- A more recent example of creative destruction involves the retailing giant Walmart.

9-5 Conclusion

1. Long-run economic growth is the single most important determinant of the economic well-being of a nation's citizens.
2. The Solow growth model and the more recent endogenous growth models show how
   a. saving,
   b. population growth, and
   c. technological progress

   interact in determining the level and growth of a nation's standard of living.

THANKS !